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Matsushita Communication Industrial Corporation of America

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November 10, 1993

Office of the Secretary
Federal Communications Commission
Washington, DC 20554

RE: Comments on the Commission's Notice of Proposed Rule Making
ET Docket No. 93-62

Dear Sir or Madam:

Enclosed please find one original and nine (9) copies of Comments prepared by this organization in response to the Commission's Notice of Proposed Rule Making.

Please contact the undersigned if upon review of these comments the Commission desires further explanation, or desires engineering analysis to support said comments. You may also contact the undersigned by phone at (404) 740-2115, or via facsimile at (404) 740-8781.

Thank you for your consideration.

Sincerely,

A Rois-Méndez

Armando Rois-Méndez
Legal Coordinator

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Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of:	)	
	)	
Guidelines for Evaluating the Environmental Effects of Radiofrequency Radiation	)	ET Docket No. 93-62
	)	

COMMENTS FROM
MATSUSHITA COMMUNICATION INDUSTRIAL CORPORATION OF AMERICA
[MCC/Panasonic]

[Comments Emphasize Interpretations And Clarification Of The
ANSI/IEEE C95.1-1992 Standard
As It Applies To Portable And Handheld Low-Power Devices]

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November 10, 1993

TABLE OF CONTENTS

SUMMARY

These Comments ask for clarification, and propose interpretations that are consistent with the purpose of the ANSI/IEEE C95.1-1992, the FCC and NEPA's goals. Unlike a purely technical product standard, the proposed Standard has some ambiguities that later on may be interpreted subjectively. These comments ask for clarification and interpretations to eliminate these ambiguities. This will ensure that the industry knows what it must do to comply with the new Standard.

The purpose of the ANSI/IEEE C95.1-1992 (Standard) is to make recommendations "to prevent harmful effects in human beings exposed to electromagnetic fields."[1] Consistent with this purpose, the ANSI/IEEE C95.1-1992 authors discuss that lack of knowledge gives rise to conservative assumptions.[2] They also discuss how the 1982 Standard (ANSI/IEEE C95.1-1982) explicitly invoked a safety factor of 10, "but incorporated numerous 'conservative assumptions' or implicit contributions towards 'safety.' "

These conservative assumptions further add to the "safety factor" imposed by the Standard. Thus, *"[t]he collective import of these "conservative" assumptions is to provide a degree of safety or freedom from hazard for a given human over time and space much greater than is implied by the explicit safety factor of ten."*[3] Emphasis added.

The clarification and proposed interpretations in this document are not a softening or stretching of the Standard to favor the industry. However, since the Standards' levels are admittedly conservative, these comments ask for clarification, and propose interpretations, consistent with the following premise: devices, or parts of a device that radiate power at *much lower levels* than the Standard's controlled and uncontrolled environment, should not require certification.

1. <u>Definition Of Radiating Structure And Low-Power Exclusion For Such Structures.</u>

This document proposes to clarify the definition "Radiating Structure" as the antenna and other parts of the device intended to radiate RF energy into space. This

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1 <u>Scope and Purpose</u>, ANSI/IEEE C95.1-1992, page 9.
2 Section 6.5, <u>Safety Factors</u>, ANSI/IEEE C95.1-1992, p 28.
3 Ibid., p 29.

definition excludes low-power incidental radiators such as the housing, or components within the device.

This document proposes that parts of a device that radiate RF energy at levels ten times lower than allowed under the Standard's uncontrolled environment should *not* be considered radiating structures.

2. Low-Power Exclusions - SAR Averaged Over A Cubic Shaped Tissue Volume.

Both, the controlled and uncontrolled environment have low-power exclusions where the spatial absorption rate (SAR) should be averaged over a volume "the shape of a cube."[4] Are the following interpretations correct? On thin tissue, such as the ear, one draws an imaginary cube (which includes air and tissue) and average the power over this volume. On thick tissue, the SAR is averaged over a one centimeter[5] depth in the tissue. The SAR would be higher at the surface, since its closer to the radiator, and lower at one centimeter depth. Nevertheless, the average over this one centimeter is the parameter controlled by the Standard.

3. Manner Of Usage Used To Measure Distance From Radiating Source For The Purpose Of SAR Measurements Or Low-Power Exclusions

To certify a product one should look at how the device is intended to be used and is actually used. One need not engage in unrealistic or far-fetched "what if" scenarios on the mode of use. For example, if a handheld device is put against the ear in some typical manner, this typical manner of usage should be used on determining compliance. Similar reasoning would apply to car mounted or transportable devices.

4. Analytical Means To Show Compliance With The New Standard.

This document asks that the FCC approves some analytical techniques as appropriate *to verify* and later *to certify* the compliance of a new radio or cellular telephone design with the Standard. Reputable authorities in RF energy absorption have shown the accuracy of some such analytical techniques.[6] *Furthermore, analysis would allow the industry to show compliance even in the absence of certified test laboratories!*

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[4] NPRM, Appendix A, pp. 22-23 and C95.1, p 17.

[5] For the uncontrolled environment. Assumes a tissue density of one gram per cubic centimeter.

A new radio or cellular telephone typically has a two-year design cycle. During this cycle the design evolves from a paper concept, to laboratory testing, to production. The cost and time necessary to change a product's design increase significantly as the product proceeds from its initial stages, into production. At the production stage, major design changes typically become so expensive as to be impractical. Therefore, it is important that the engineers have analytical tools to predict the behavior of the device, long before the device goes into production.

5. Exclusion Of Very-Low-Power Devices From Proving Compliance.

Certification should not be required for very low power devices. For example, for devices that radiate energy at levels ten times lower than under the Standard's uncontrolled environment. Thus, cordless telephones, or other very low power devices (for example children's radios, remote controlled toys, etc.), should not require type certification under the Standard.[7]

Also, the required distance to the source for low power devices should be adjusted according to the transmitted power. For example, for an uncontrolled source the exclusion power is 1.4 (450/f) Watts when the radiation source is at least at 2.5 cm. An inverse distance relationship[8] would allow the power to be 0.7 (450/f) Watts when the radiation source is at 1.25 cm.

6. Can The Industry Use Average Transmitted Power To Show Compliance?

The transmission power for some devices, for example, cellular telephones, is controlled by a base station. For example, even if the device is rated at say 0.6 Watts, the average transmitted power may be no more than 0.2 Watts. Can the industry use these average powers to show compliance with the Standard?

[6] See text below, for a discussion of said methods.

[7] With the possible exception of devices (unknown to the authors) where the antenna or radiating structure has to be in intimate contact with the body.

[8] At close range to a line source the power decreases linearly with distance. For a point source the power decreases at an inverse square relationship. See further discussion in §F below.

A.

INTRODUCTION

1. Qualifications.

The Matsushita Communication Industrial Corp. of America (MCC/Panasonic) is a leading manufacturer of cellular mobile telephones, digital business telephone systems, pagers and car audio. Located in Georgia, MCC Panasonic has a 70,000 square ft. factory facility in Peachtree City, Georgia, with about 800 employees, and a 30,000 square ft. engineering facility in Alpharetta, Gerogia, with about 80 employees.

The principal author of these comments has over fifteen years of technical experience with the industry, much of it in communications. The author has an M.S.A.E. from Purdue University, an M.S.E.E. from Polytechnic University of New York (formerly Brooklyn Polytechnic Institute), a J.D. from Southwestern University School of Law (California) and has been admitted to practice law in Georgia.

2. Purpose Of These Comments.

MCC/Panasonic believes that the clarifications and interpretations proposed here will be of significant help to the industry, the consumers and the governmental agencies. These comments are proposed using both, a technical and legal rationale. In these comments, the author does not argue far-fetched interpretations to favor the industry. Instead, the author offers technically sound rationale, consistent with the enunciated objectives of the FCC and the ANSI/IEEE Standard.

Interpretations of the Standard that now seem obvious may later be challenged by the Commission, the public, or the industry. Thus, MCC/Panasonic believes, this is the best time to clarify these concerns.

3. Terminology.

This document refers to the ANSI/IEEE C95.1-1992 Standard, as the Standard, or as C95.1. The FCC's Notice of Proposed Rule Making, ET Docket No. 93-62, is referred to as NPRM, followed by paragraph (¶) number if appropriate. The Federal Communications Commission will be referred to as the FCC or as the Commission.

B.

LOW POWER DEVICES/EXCLUSIONS -- DEFINITION OF RADIATING STRUCTURE. [NPRM ¶ 17]

1. The Words "Radiating Structure" Are Ambiguous.

The radiated power exclusion does not apply when the radiating structure is within 2.5 cm of the body.[9] Furthermore, radiating structure may include parts of the device "other than the antenna itself."[10] Strictly speaking, even radiation that is millions of times smaller than allowed under the Standard falls within this definition. This renders the low power exclusion inapplicable to all handheld and possibly all portable devices. Since this defeats the purpose of the low-power exclusions, this open definition is ambiguous.

The authors maintain that *all radios (this includes all cellular telephones) radiate some energy* from parts of the device other than the antenna. In these devices the antenna is the principal radiator. Also, a part may have been designed to radiate energy. Such a part, whether or not it looks like an antenna, is an antenna. As such, these radiating parts are properly subject to the Standard and the NPRM's power and distance requirements.

Nevertheless, it is impossible to prevent RF radiation from other parts of the device. In general, the "incidental" radiation from the device, other than intended radiators, is small, being anywhere from ten times to millions of times lower than the actual power radiated by the intended radiators.

The experts that prepared the ANSI/IEEE C95.1-1992 Standard knew that a device could be designed such that a part of it, other than the antenna, emitted significant radiation. Thus, they use the words "radiating structure" in the Standard to include such intended radiators.

However, these experts also knew that many electronic components radiate energy, and that all radios and cellular telephones emit some stray or incidental radiation from parts of the device other than the intended radiators. Still, these experts included a

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9 NPRM ¶17, and C.95.1, ¶¶ 4.2.1.1 and 4.2.2.1.
10 NPRM ¶17.

low-power device exclusion in the Standard. They added this exclusion to eliminate the burden of testing low power devices, since these devices do not pose a health risk.[11] Since all radios emit *some* RF from parts other than the antenna, then it defeats the purpose of the exclusion to disqualify a radio if it emits some incidental RF.

2. <u>A Clear Definition, From The FCC, Of What Constitutes A Radiating Structure Will Speed-Up The Certification Process.</u>

The authors of C95.1 state that the Standard is very conservative. Though it is hard to assess what the factor of safety is, the authors admit that it may be significantly higher than ten. Radiation from a part of a device that is ten times lower than that allowed under the Standard would, in effect, have a *factor of safety significantly higher than one hundred.* Thus, this author proposes the following definition: "Radiating Structure" is any part of the device that radiates energy at more than ten percent of the power allowed under the Standard's low-power device exclusion for controlled and uncontrolled environments.

The C95.1 authors state that lack of knowledge gave rise to conservative assumptions.[12] They also discuss how *the 1982 Standard* (ANSI/IEEE C95.1-1982) explicitly invoked a safety factor of 10 and "incorporated numerous 'conservative assumptions' or implicit contributions towards 'safety.' "

These conservative assumptions further add to the "safety factor" imposed by the Standard. Thus, *"[t]he collective import of these "conservative" assumptions is to provide a degree of safety or freedom from hazard for a given human over time and space much greater than is implied by the explicit safety factor of ten."*[13] Emphasis added.

Note that these conservative levels correspond to the 1982 Standard. The C95.1, 1992 Standard is still more restrictive and conservative,[14] incorporating additional safety factors for the uncontrolled environment.[15]

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11 Based, of course, on current state of knowledge.
12 Section 6.5, <u>Safety Factors</u>, ANSI/IEEE C95.1-1992, p 28.
13 Ibid., p 29.
14 See NPRM ¶ 6.
15 ANSI/IEEE C95.1-1992, Section 6.5, p 29.

Given the safety factors used in the 1982 Standard, given the additional safety factors superimposed for the uncontrolled environment, and given that all radios radiate some energy from parts other than the antenna, it seems reasonable to define radiating structures in a manner that still allows the industry to use, when appropriate, the low-power controlled and uncontrolled environment exclusion. Thus, parts of a device that radiate power at levels ten times lower than the Standard allows, should not be considered or treated as radiation devices.

3. For Most Of The Industry, Testing May Be A Burdensome And Impractical Alternative.

NPRM Paragraph 17 states that where the radiating structure includes parts of the device, other than the antenna, the manufacturers may show compliance by appropriate measurements. Appropriate measurement methods, however, are not yet available. Even when they become available, more than likely the measurement methods will have accuracy and spatial limitations.[16] Also, testing will probably be expensive and time consuming.

MCC/Panasonic does not question the need of measurement in cases where the part of the device being tested is an intended radiator (as defined above). However, requiring measurements, when the level of radiation is so small (i.e., the ten percent rule discussed above), seems an unnecessary burden.

[16] See published discussions on the size of the probes and methods used to simulate human tissue. For example, N. Kuster and Q. Balzano, *Energy Absorption Mechanism by Biological Bodies in the Near Field of Dipole Antennas Above 300 MHz*, IEEE Transactions on Vehicular Technology, Vol. 41, No. 1 (February 1992). Hereafter, Balzano, *Energy Absorption Mechanism*. See also, L. Martens, et. al., *Electromagnetic field calculations used for exposure experiments on small animals in TEM-cells*, Bioelectrochemestry and Bioenergetics, 30 (1993).

C.

LOW POWER DEVICES/EXCLUSIONS -- SAR AVERAGED OVER

A CUBIC-SHAPED VOLUME OF TISSUE.

The NPRM and the Standard state that for the low-power exclusions, the SAR is averaged "over any 1 g of tissue (defined as a tissue volume in the shape of a cube)"[17] The SAR in the hands, wrists, feet and ankles is "averaged over any 10 g of tissue (defined as a tissue volume in the shape of a cube)." The authors asks whether the interpretation given below is correct.

Assume a density of human tissue to be about one gram per cubic centimeter. then, the SAR required under the exclusion would be the SAR averaged over a one centimeter cube. On thick surfaces, one would average the SAR over a the one centimeter thickness. On thin tissue, such as the ear lobe, the cubic-volume rule means that the SAR is averaged over a one centimeter depth. This one centimeter includes ear lobe tissue and air space.

Based on the same 1 gram per cubic centimeter assumption, the SAR on the hands would be as averaged over a cubic volume 2.15 cm on each side.[18]

D.

MANNER OF USAGE DETERMINES DISTANCE TO SOURCE

The design of a device dictates its inherent mode of use. This mode of use should be used to determine compliance with the Specification requirements. Thus, the industry would not have to consider far-fetched, "what if" use scenarios to determine compliance.

NPRM paragraphs 7, 15 and 17 mention the 2.5 cm distance from the body. How should the distance be measured and what constitutes the body. Initially, the answers seem self-evident. However, on closer inspection the answers are elusive. MCC/Panasonic asks that distance be measured based on the typical or recommended form of usage. This excludes the purposeful touching of the radiating distance. It also

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17 NPRM ¶17, and C.95.1, ¶¶ 4.2.1.1 and 4.2.2.1.

18 This is the cube root of 10.

This excludes the purposeful touching of the radiating distance. It also excludes exaggerated, nonsensical, ways of using the telephone or RF transmitting device.

For example, a car mounted radio has an antenna typically installed on the roof or on a side or rear window. In its typical use mode, the driver and passenger are several inches away from the source and typically shielded from the source by a metallic roof. Thus, it is acceptable to consider that a person is several inches away from the radiation source when determining compliance with the Standard.

On a portable radio, the antenna is typically located on the transmitter. The transmitter is typically held in one hand via a handle or strap, or placed on a surface such as a desk or table. The user holds the receiver or microphone in the other hand. Thus, only the user's hand may be close to the radiating structure, and typically several inches away from it. Here, compliance would be determined with a typical distance from the radiation source to the body and typical distance to the hand. The industry would be able to certify the device based on SAR analysis or test and based on adequate instructions, to the user, to keep the antenna at a given distance from the body (say 10 cm) and not to touch the antenna.

On a handheld radio, the antenna is typically attached to the receiver and the user places the receiver close to his or her mouth and ear. As in the above case, the industry would design the device such that, in normal usage, the antenna maintains a minimum distance from the body, e.g., 2.5 cm. The industry would be able to certify the device based on SAR analysis, test, or the low-power exclusion and based on adequate consumer instructions on the proper manner to use the device and instructions not to touch the antenna.

E.

LOW POWER DEVICES/EXCLUSIONS -- COMPLIANCE DEMONSTRATION.

[NPRM ¶ 17]

1. In The Design And Development Of New Products, The Engineering Industry Must Rely On Analytical Techniques And Readily Available Laboratory Tools.

A new radio or cellular telephone typically has a two-year design cycle. During this cycle the design evolves from its initial paper concept to production. During the design process the engineers make numerous tradeoffs in the selection of components for the device. In these tradeoffs, the engineers predicts, via analysis, the behavior of the telephone if one component is used instead of another. The final design is the distillation of the numerous analytical and test trade-offs into a workable product.

During the initial stages, it is not too expensive or time consuming to make changes in the design. At this initial stage the design is not constrained by a multitude of parameters. As the design proceeds to completion numerous decisions have been made that constrain the choice of a component. Later, a change is not so easy. For example, if a component has to change, it may cause the relocation of other components in a circuit card, this may require redesign of the circuit card, which in turn may require redesign of the housing and other components within the housing.

Therefore, the engineer cannot wait until a product is finished to see if it satisfies certain requirement. The engineer needs to have and relies on analytical tools (mathematical analysis) and laboratory techniques to predict the final result. It would not be enough for an engineer to say" we don't know if this will pass, we'll just have to wait and see." The engineer must know, with some level of confidence, that his design will meet certain criterion.

Thus, the FCC should approve some analytical techniques as appropriate *to verify* and later *to certify* the compliance of a new radio or cellular telephone design with the Standard. The FCC should allow the industry to demonstrate compliance via mathematical analysis. If the Commission finds that a test is still necessary, it should be used to verify that the mathematically predicted results do not deviate *impermissibly* far from the test results.[19]

2. Testing, Instead Of Analysis, On A Two-Year, Multi-Million Dollar Design Cycle May Be An Expensive Alternative.

For the reasons stated above, testing after the product has been designed may be too expensive and impractical of an alternative. At the end of the design cycle, too many engineering decisions have been made, too many contracts have been awarded and too much spent in tooling.

With adequate mathematical tools, the industry will strive to design a device that meets the Commission's requirements. They can make design changes, to ensure compliance, while it is early enough in the device's design to do so.

3. Authoritative Technical Publications Show That Analytical Techniques For SAR Accurately Predict Test Results.

Scientists knowledgeable in the absorption of RF energy and knowledgeable with the old and new ANSI/IEEE C95.1 Standard, have published well documented articles showing how to calculate and predict energy absorption by human tissue from a very close RF radiator. See, for example, N. Kuster and Q. Balzano, *Energy Absorption Mechanism by Biological Bodies in the Near Field of Dipole Antennas Above 300 MHz,* IEEE Transactions on Vehicular Technology, Vol. 41, No. 1 (February 1992) [hereinafter the IEEE paper or Balzano, *Energy Absorption Mechanism*]. See **Exhibit A**.

In the IEEE paper, the authors dedicate a significant portion of the document discussing the accuracy of their mathematical method and how closely (to engineering standards) it approximates the actual test data. Drs. Balzano and Kuster conclude: "the correspondence between approximation and actual spatial peak SAR is well within 3 dB. *This is excellent*, especially if one considers the large variations of the absolute spatial

[19] The publications discussed below show that for distances smaller than 0.1 wavelength (distance smaller than 1.5 inches for cellular band telephones) the analysis predicts results that range from 0.5 dB too small to 2.5 dB too large. Test results that verify compliance within these levels should be considered adequate.

peak SAR, which is well over 30 dB in the above cases."[20] The authors further state "[a]ccurate worst-case SAR approximations are obtained applying [the equations] for the human body exposed to close near fields of dipole antennas operating above 300 MHz."[21]

F.

LOW POWER DEVICES/EXCLUSIONS -- RELATIONSHIP BETWEEN POWER OUTPUT VS. DISTANCE FROM RADIATING SOURCE.

[NPRM ¶ 7, 15-18]

1. A Testing Or Compliance Exclusion, For Very-Low-Power Devices, Would Be Consistent With The New Standard's Purpose.

Following a rationale similar to that presented in section B, above, it would seem unnecessary to require testing and verification of compliance for devices where the total radiating power is low compared to that allowed by the Standard. Thus, if for a given frequency, the Standard allows RF power of 0.7 Watts, it seems unnecessary to require testing and certification for those devices with a maximum radiating power of 0.07 Watts (ten times smaller).

This recommendation is consistent with the Standard and the fact that it incorporates a factor of safety greater than ten. Thus, only those devices whose power output result in a factor of safety greater than one hundred would be excused from the need to show compliance.

2. Adjustment To The Allowable Distance From The Source Based On Relationship Between Power And Distance.

The Standard provides a formula for the calculation of allowable power for a given frequency. For the controlled environment the power is 7 (450/f) Watts, for the uncontrolled environment it becomes 1.4 (450/f) Watts. Both of these requirements have a further requirement that the source be maintained at a minimum distance of 2.5 cm from the body. If not, the manufacturer must demonstrate compliance by testing. Here again, it

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20 IEEE paper, page 21. See section C(3) above, and accompanying text.

21 Ibid.

would be consistent with the Standard to allow lower power devices to qualify even if the distance to the radiating source is closer than 2.5 centimeters.

Power, from a point source, obeys an inverse square law. However, for an infinite line source this relationship becomes simply an inverse (linear) law. Thus, at very close distances, an antenna can be treated as a line source. Thus, the 1.4 (450/f) Watts for a 2.5 cm source distance from the body becomes 0.7 (450/f) Watts for a source distance of 1.25 cm from the body.

This adjustment of power to distance would allow a manufacturer to certify slim-line telephones, even if the radiating source violates the 2.5 cm requirement, As long as the power is reduced correspondingly.[22] Again, this interpretation is consistent with the stated purpose of the Standard.

G.

CAN THE INDUSTRY USE AVERAGE TRANSMITTED POWER TO SHOW COMPLIANCE?

The transmission power for some devices, for example, cellular telephones, is controlled by a base station. In these devices, the power output can be varied between 0.006 Watt to 0.6 Watt for handheld telephones and 0.006 Watt to 3.0 Watt for car mounted telephones.[23] Therefore, even if the device is rate at say 0.6 Watts, it generally transmits at lower powers. The average transmitted power may be no more than 0.2 Watts. Can the industry use these average powers[24] to verify compliance with the Standard?

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[22] Note that Balzano, *Energy Absorption Mechanism*, derives an inverse square relationship to predict the SAR. However, Figure 8, in the referenced article, shows that for very short distances (less than 0.15 wavelength) the mathematically predicted SAR exceeds the test values. At distances closer than 0.05 wavelength the difference between predicted and measure reach about 3 dB. At these closer distances the antenna looks more like a uniform line source. An inverse law, for these short distances might yield a closer approximation than the inverse square law.

Note that in the IEEE paper, the authors state that the predicted SAR levels are "accurate worst-case. . ." See IEEE paper, page 21.

[23] Actually, the base station directs the telephone to transmit at certain power. If the requested power is too high, the device will simply transmit at its maximum power.

[24] Calculated by some in-depth study over a large enough population.

CONCLUSION

The clarification and interpretations proposed in this document are consistent with the stated purpose of the Standard. The Standard was issued as a set of recommendations to the industry. As a recommendation, it didn't matter if one industry took a slightly different interpretation than another. What mattered was that the industry, as a whole, followed the general spirit of the recommendations. With its adoption, the character of the Standard changes. It is no longer a list of recommendations. An innocent mistake or misinterpretation by a manufacturer can cause significant costs and delays. Some forethought and interpretations of the Standard should help the industry and the FCC meet the objectives of the Standard, "to prevent harmful effects in human beings exposed to electromagnetic fields in the frequency range from 3 kHz to 300 GHz."

Respectfully submitted, this 10 day of November, 1993.

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PAPERS

Communications

Energy Absorption Mechanism by Biological Bodies in the Near Field of Dipole Antennas Above 300 MHz

Niels Kuster and Quirino Balzano, *Senior Member, IEEE*

***Abstract*—The energy absorption mechanism in the close near field of dipole antennas is studied by numerical simulations. All computations are performed and validated applying the three-dimensional multiple multipole (3DMMP) software package. The numerical model of the plane phantom is additionally checked by accurate as possible experimental measurements. For the plane phantom, the interaction mechanism can be well described by H-field induced surface currents. The spatial peak specific absorption rate (SAR) can be approximated within 3 dB by a formula given here based on the incident H-field or antenna current and on the conductivity and permittivity of the tissue. It is further shown that these findings can be generalized to heterogeneous tissues and larger biological bodies of arbitrary shape for frequencies above 300 MHz. The SAR is found to be mainly proportional to the square of the incident H-field, which implies that in the close near field, the spatial peak SAR is related to the antenna current and not to the input power. Another consequence of this study is that the exclusion clause of the ANSI C95.1-1982 standard for low-power communication equipment must be revised because it is in direct contradiction with the basic peak SAR limits.**

I. Introduction

PORTABLE hand-held communication transceivers are becoming widely used consumer products. The market for cellular telephones is growing sharply. New digital systems with new specifications (GSM, DECT, USDC, JDC) are currently being introduced or are anticipated to become communication standards in this decade. Parallel with the wider use of such devices, public concern about their safety has grown. Representatives of different environmental protection agencies have recently questioned the 7-W exclusion clause, which is based on rather poor physical considerations. The 7-W exclusion clause introduced in 1982 in the ANSI C95.1 safety standard [1] excludes all transceivers operating below 1.5 GHz and radiating less than 7 W from assessing its compliance with the basic safety limits. This clause was adopted worldwide by most standard-setting organizations and was initially retained by the ongoing revision of the ANSI Limits [2] despite dissenting opinions in the committee [3].

In the literature, a number of studies concerning RF absorption in the near field of antennas are cited. The majority of these cover the frequency range below 100 MHz. Several studies investigated the frequency range of hand-held radios between 300 MHz and 3 GHz. Experimental studies were performed on homogeneous or layered plane phantom models [4]–[6] and homogeneous human models [4]–[8] or heterogeneous human models simulating anatomical details [9]–[11]. These models were either radiated by laboratory dipoles or commercially available transmitters. Numerical computations were performed simulating homogeneous or layered spheres [12], [13] and homogeneous [14] or blockwise heterogeneous [9], [15] human models. Comparing the results, one notes that specific absorption rate (SAR) values are quantitatively not always consistent and some results and differences are even qualitatively not satisfactorily explainable in physical terms.

This lack of clear knowledge about the absorption mechanism of near fields motivated this study. Another goal, also related to the absorption mechanism, was to find a simple relation between the incident field strengths in the vicinity of dipole-like sources and the corresponding worst-case exposure SAR values. Such an approximation based on free-space field values would be advantageous regarding the enforcement of safety limits because SAR measurements are costly and not always possible.

The standard scientific approach to extracting a principal mechanism is to simplify the "real-world" model as much as possible in order to avoid any disturbing secondary effects. The implicit assumption that the extracted mechanism is transferable to more complex structures under consideration of secondary effects has to be validated afterward. The same approach is taken in this study. The human model is initially reduced to a simple homogeneous half-space phantom in order to avoid any focusing effects and complex disturbances due to heterogeneous tissue. Analyzing this very basic phantom, the absorption mechanism and an approximation are extracted. Their range of validity is then extended to arbitrary bodies by studying curved surfaces and partwise heterogeneous bodies.

II. Measurement Method

The experimental setup is shown in Figs. 1 and 2. It was initially developed to study communication antennas worn at the belt and has been modified for this study in order to increase its accuracy. The phantom is a parallelepipedal box (acrylic glass 5-mm thick) of 50 × 30 × 15 cm filled by muscle-simulating material, as described in [9]. The relative

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IEEE Log Number 9105389.

Fig. 1. Experimental setup. The laboratory dipole shown in Fig. 2 is used instead of the commercial transceiver, which is visible below the box.

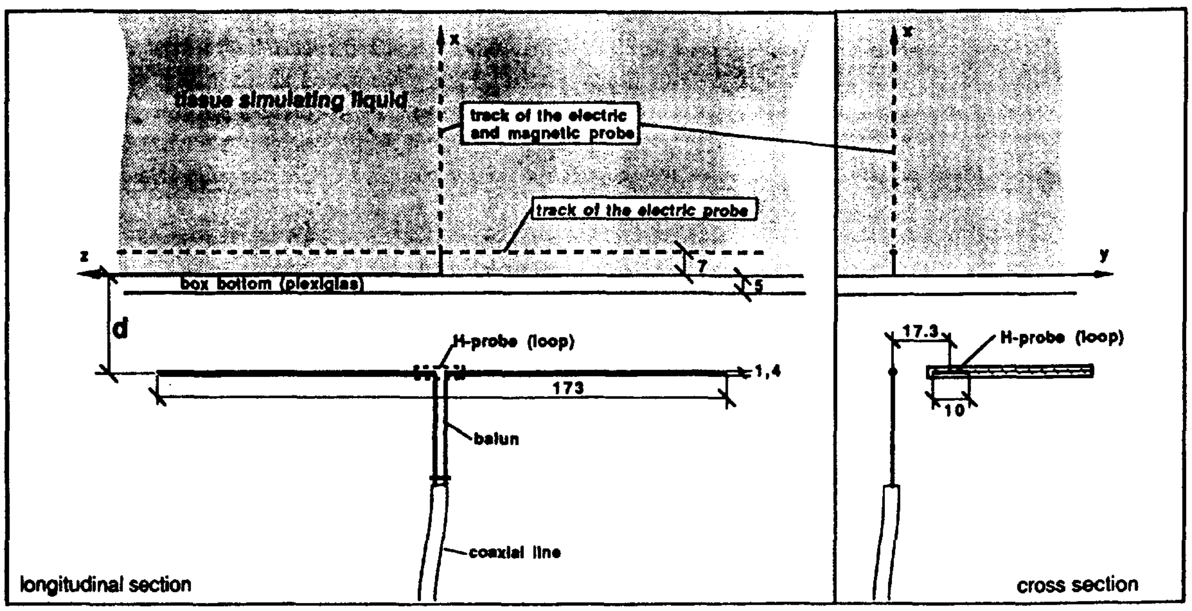

Fig. 2. Longitudinal and cross-section drawing of the experimental setup (distances in millimeters).

permittivity and conductivity at 840 MHz measured according to the coaxial line attenuation method was $\epsilon_r = 53 \pm 1$ and $\sigma = 1.4 \pm 0.1$ mho/m, respectively.

The measurement is controlled by a computer (IBM PS/2)-managed data acquisition system. The E- and H-field probes are positioned by an Intelledex MicroSmooth Robot model 660. The positioning accuracy of the robot is ± 1 mm. The E-field sensor and relative optoelectronics is manufactured by EIT of Sterling, VA. The H-field probe has a 1-cm diameter loop sensor fabricated following the technology of the E-field probe.

The E- and H-field probes are calibrated before and after the measurement session using a transverse electromagnetic cell, manufactured by IFI, model number CC-110. The calibrations are estimated to be within $\pm 1\%$ for the H-field probe and $\pm 6\%$ for the E-field probe. The uncertainties for the E-field probe are larger because of the slightly anisotropic probe and the permittivity correction factor (the calibration is performed in air).

The RF source used in the measurements is a dipole 173 mm long and 0.7 mm in diameter adapted to the line by a wide-band balun and driven by an HP8753C generator and a

Hughes 46111H amplifier. The forward and reflected power is monitored by a bidirectional coupler Narda 3020A and HP 435B power meters. The losses in the line and balun are measured and taken into account (accuracy 0.1 dB). The distance between antenna and tissue surface was set by spacers with an accuracy of better than 0.5 mm.

From the beginning it was obvious that only the free-space H-field pattern qualitatively tracks the SAR distribution in simulated tissue. The reasoning is that the E-field undergoes radical structural changes in presence of lossy dielectric bodies, whereas the current distribution on the antenna is less affected. However, it is well known that the feedpoint impedance is affected in the close vicinity of conductive scatters that may substantially change the amplitude of the antenna current. This was also confirmed by the initial experiments and computations. The feed-point current I_{fp} was therefore measured by an additional H-field probe placed as close as possible on the side of the antenna (Fig. 2). The measured values are slightly distorted by unwanted reflections but by less than ±5%.

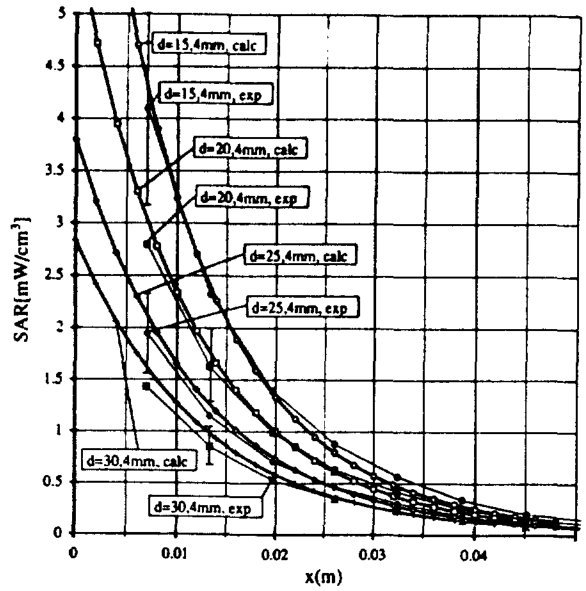

Fig. 3. Comparison between computed and measured SAR values at the antenna feedpoint versus depth into the simulation tissue for different distances d (see Fig. 2). All values are calibrated to an antenna current of 100 mA. The attenuation is about 20% stronger than that of a corresponding plane wave.

III. Numerical Method

The numerical computations are performed with the three-dimensional multiple multipole (3DMMP) program package, which is based on the generalized multipole technique (GMT). This technique as well as its MMP implementation are described elsewhere [16]–[19]. The code is especially well suited to compute highly accurate near-field problems within lossy bodies [14] and has also been tested to be rather efficient compared to other codes for canonical problems of this type [20], [21].

The dipole antennas that varied in length and thickness are simulated by axis-symmetric wire expansions. Because a good simulation of the antenna tips, especially in the case of antenna lengths close to $n\lambda$, is essential to achieve highly accurate antenna models, the ends are modeled as half-spheres, and two multipoles are added at the end to supplement the wire expansions. The feed source is simplified by collapsing it into a small gap (0.45 times antenna diameter) located in the center of the dipole. The feedpoint impedance is computed by integrating the E-field over the feeding gap. Its accuracy is estimated to better than 2%.

The flat phantom is modeled with a quarter of a plane finite surface (radius $\gg$ wavelength λ) using two planes of symmetry. About 1200 matching points have been used, the density of which continuously decreased from the center to the edge of this surface. The number of matching points for the biological spheres is adapted to the number of expansions needed.

The backward interaction of the scatterer on the antenna is neglected in the first step in order to simplify the validation. The interaction between the two is computed by the interative technique described in [17], [22]. Good convergence is already achieved in the second step.

IV. Validation

The numerical models are validated twice. The first is quite extensive. The results of different matching point distributions with varied locations and order of the expansions is compared and tested with the internal check routines developed for the MMP program package that have been proven to be reliable [23]. The determined accuracy of SAR and H^2 based on these internal checks varies between 1–10% depending on material and the distance from the source to the surface. In addition, the total power absorbed and radiated into free space is checked to be equal with the power available at the feeding gap.

In the second validation, the match between numerical model and experimental results is checked. The experimental setup is numerically simulated by an identical as possible model (same antenna dimension, frequency, material properties, etc). The tested distances d between antenna axis and surface of the tissue simulating material are 15.4, 20.4, 25.4, and 30.4 mm. For geometrical details see Fig. 2. In Fig. 3, the SAR values versus depth into the simulated tissue at the location nearest to the dipole feedpoint are shown. The corresponding H^2-field values are plotted in Fig. 4. Comparisons of the SAR values along the antenna axis are also given in Fig. 5. The error bars, only plotted for certain points in Figs. 3–5 to avoid cluttered figures, are calculated from the above estimated uncertainties for the experimental values (in the calibration of the probes, in the positioning of the antenna and the probe, in the line losses, and by unwanted reflections). The good correspondence between experimental and numerical data lends strong confidence to the results.

V. Result of the Planar Model

In the first step, the distance between antenna and phantom is varied for different setups from several λ to fractions of λ. The spatial peak magnetic field at the surface of the plane

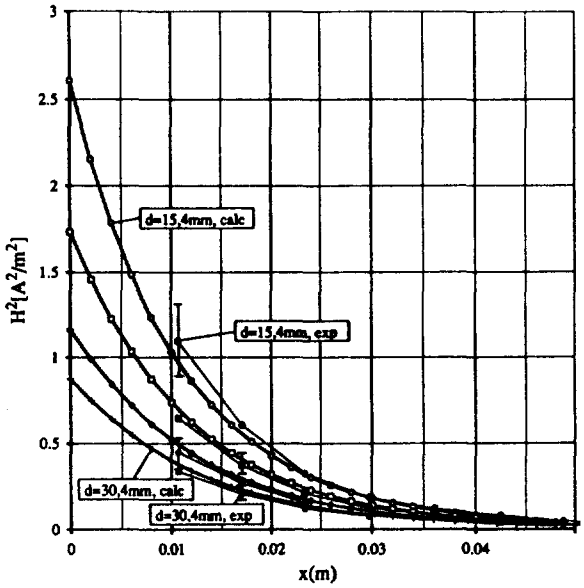

Fig. 4. Comparison between computed and measured H^2 values at the antenna feedpoint versus depth into the simulation tissue for different distances d (see Fig. 2). All values are calibrated to an antenna current of 100 mA.

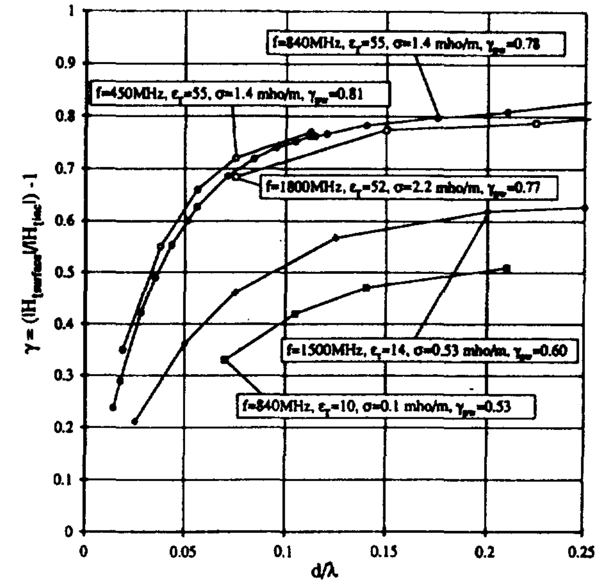

Fig. 6. The reflection coefficient γ versus the distance of the antenna from the surface in terms of wavelength d/λ is plotted for five representative examples.

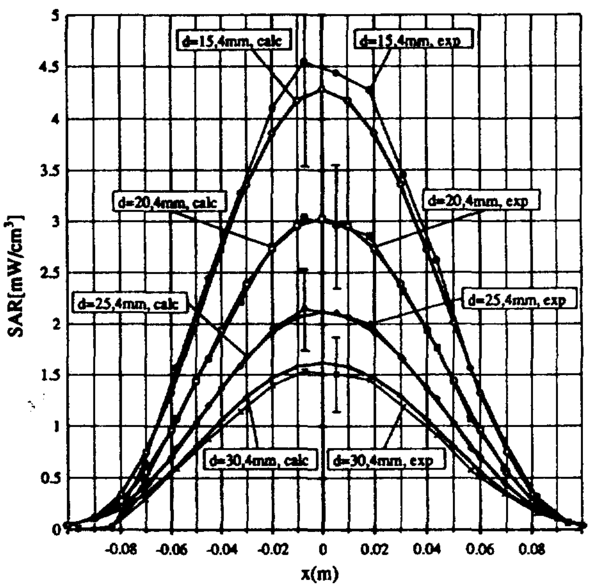

Fig. 5. Comparison between computed and measured SAR distribution along the antenna axis 7 mm behind the surface (see Fig. 2). All values are calibrated to an antenna current of 100 mA.

phantom induced by the dipole antennas is compared to those of a plane wave at normal incidences to an infinite plane. For illustration, a few values of the reflection coefficient for the H-field tangential to the scattering surface defined as $\gamma = (|H_{t_{surface}}|/|H_{t_{inc}}| - 1)$ are plotted in Fig. 6. This plot indicates that the reflection coefficient γ already approaches that of the plane wave γ_{pw} in a distance from the phantom within a quarter of the wavelength. It is also plausible that it strongly drops if the distance d becomes very small in terms of wavelength because the interaction changes from mainly radiating to mainly absorbing the power available at the feeding gap.

In addition, the ratio of $|E|/|H|$ in the tissue near the surface is compared with the wave impedance $|Z_{pw}|$ of the tissue. A few representative values are given in Fig. 7. Good correspondence was expected for materials of higher attenuation and for larger distances d because in these cases the derivatives of the fields normal to the surface become dominant to the derivatives parallel to the surface. However, Fig. 7 indicates that even in the case of poorly conductive tissues, the induced E-field $|E|$ is pretty well approximated by $|Z_{pw}|\cdot|H|$ for frequencies above 300 MHz, except for very small distances d.

VI. Approximaton Formula

These findings attempt to approximate the spatial peak SAR by using a modified analytical solution of the plane wave excitation ($e^{-i\omega t}$ time dependence).

The SAR induced at the surface of an infinite lossy plane with the permittivity ε, the permeability $\mu = \mu_0$, the conductivity σ, and the mass density ρ by a normal incident plane wave with magnetic field $H_{t_{inc}}$ (rms) can be written in the following form:

$$\mathrm{SAR} = \frac{\sigma}{\rho} \frac{\mu\omega}{\rho\sqrt{\sigma^2 + \varepsilon^2\omega^2}} (1 + c_{corr}\gamma_{pw})^2 H_{t_{inc}}^2 \qquad (1)$$

in which γ_{pw} is the plane-wave reflection coefficient for the H_t field

$$\gamma_{pw} = \frac{2\left|\sqrt{\varepsilon'}\right|}{\left|\sqrt{\varepsilon'} + \sqrt{\varepsilon_0}\right|} - 1 \qquad (2)$$

with the complex permittivity $\varepsilon' = \varepsilon - \sigma/i\omega$. The correction coefficient c_{corr} is introduced to take into account the changed reflection properties for small distances d of the antenna from

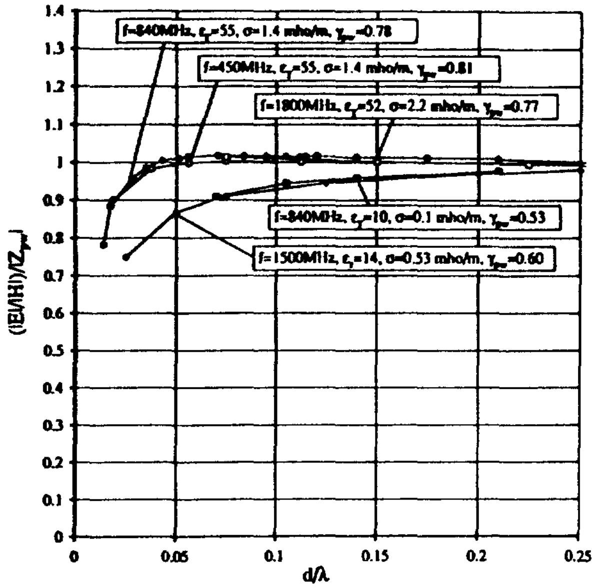

Fig. 7. Comparison between the wave impedance of the tissue $|Z_{pw}|$ and the field ratio $|E|/|H|$ at the surface inside the tissue plotted versus the distance of the antenna axis from the surface in terms of wavelengths d/λ.

the scatterer. It was empirically approximated to be

$$c_{corr} = \begin{cases} 1 & \text{for } d \geq 0.08\lambda/\gamma_{pw} \\ \sin\left(\frac{\pi}{2}\frac{\gamma_{pw}}{0.08}\frac{d}{\lambda}\right) & \text{for } d < 0.08\lambda/\gamma_{pw} \end{cases}.$$

For dipole antennas with a length of about $\lambda/2$, the approximation (1) can be rewritten by substituting the tangential H field with the antenna feedpoint current I_{fp}:

$$\text{SAR} = \frac{\sigma}{\rho}\frac{\mu\omega}{\sqrt{\sigma^2+\varepsilon^2\omega^2}}(1+c_{corr}\gamma_{pw})^2\frac{1}{4\pi^2}\frac{I_{fp}^2}{d^2}. \quad (3)$$

The approximate formula (1) is tested by comparing it with the actual spatial peak SAR's obtained by numerical computations simulating all relevant tissues. The following parameters are varied:

1) frequency between 300 MHz and 2.5 GHz
2) distance between axis of the antenna and surface of the scatterer from 3–0.02 λ
3) relative permittivity in the range of biological tissue, i.e., 10–70
4) conductivity in the range of biological tissue, i.e., 0.1–2.6 mho/m
5) length of the dipole antenna 0.1–1.0 λ.

The results are summarized in Fig. 8. The correspondence between approximation and actual spatial peak SAR is well within 3 dB. This is excellent, especially if one considers the large variations of the absolute spatial peak SAR, which is well over 30 dB in the above cases. These results imply that the major interaction mechanism is, indeed, based on H-field established surface currents similar to that observed by plane wave excitation. However, the attenuation normal to the surface is found to be slightly stronger than that of the plane wave. Another result of (3) is that in the close near field, the SAR is not directly related to the input power but to the current on the antenna because the current might strongly depend

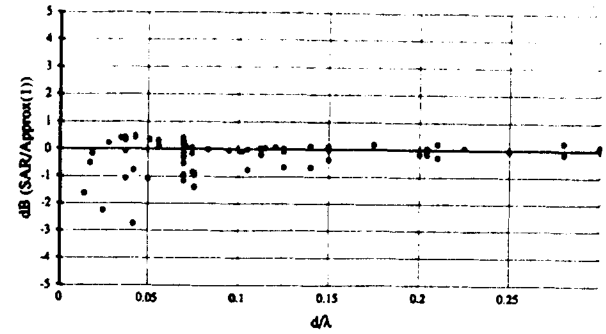

Fig. 8. The peak SAR values of various configurations are compared with those according to the approximation (1) and plotted versus the distance of the antenna axis from the surface in terms of wavelength d/λ, whereby each point represents one configuration.

on the distance from the scatterer and on the circuit-antenna design affected by changes of the feedpoint impedance.

VII. Generalization

To what extent can these findings be generalized to heterogeneous bodies of arbitrary shape? The following approach is taken to study their applicability.

First, the absorption of homogeneous spheres of different sizes and material is compared to that of the plane phantom models. Spheres are chosen to study the effects of focusing and the dependence of the reflection coefficient in function of their size. To achieve highly accurate results for spherical scatterers is simple and easily validated because multipoles consist of orthogonal functions in spherical coordinates. Therefore, the simulations for the larger spheres additionally validate the plane phantom results. Typical results are shown in Fig. 9. For large diameters, the maximal spatial peak SAR becomes equal to that of the plane phantom. The reflection coefficient γ drops with decreasing sphere diameter compared to the wavelength, which is physically reasonable. Focusing mainly affects the attenuation inside the sphere for larger diameters. Hotspots exceeding surface SAR maxima are only observed under special conditions similar to the findings for plane-wave exposure [24]. For small diameters the SAR drops linearly with radius, as predicted for absorptions caused by induced eddy currents.

Second, the absorption of a thin-layered plane phantom model was studied. Typical results are shown in Fig. 10. The following effect is observed. The layer can improve or lower the match of the incident fields to the lossy material, which results in a higher or lower reflection coefficient and, therefore, in slightly higher or lower spatial peak SAR's than according to the approximation (1). However, the effect does not essentially change the absorption, and therefore layered bodies can also be well approximated by (1). In addition, a three-domain phantom model consisting of tissues similar to eye, bone, and brain, (see Fig. 11) was simulated. These results underline that no general change of the absorption mechanism need be expected due to heterogeneous

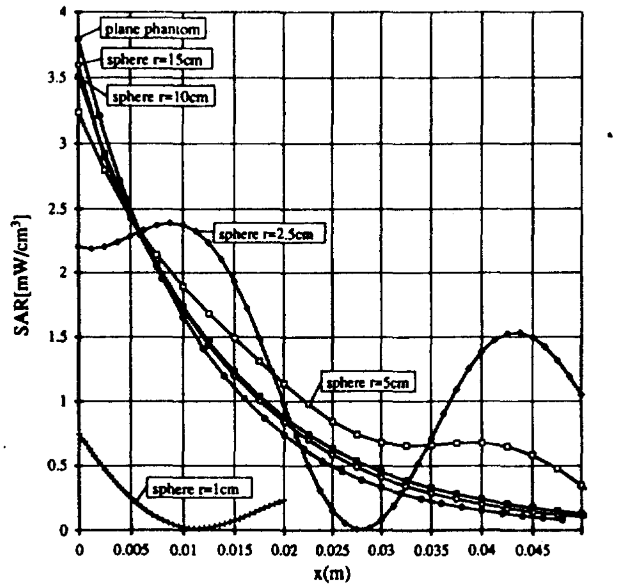

Fig. 9. The absorption of the plane phantom is compared with the absorption in spheres of different radius r consisting of the same material ($\varepsilon_r = 55, \sigma = 1.4$ mho/m) and using the same $\lambda/2$ dipole excitation (840 MHz, $d = 25$ mm). All values are calibrated to an antenna current of 100 mA.

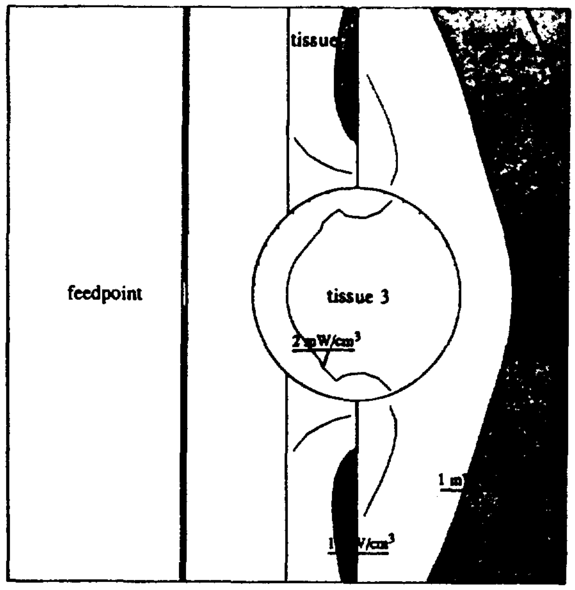

Fig. 11. SAR distribution inside a three-tissue phantom. The electric properties and geometry of tissue 1 and 2 correspond to the phantom of Fig. 10. In addition a sphere of 30 mm in diameter consisting of simulated eye tissue (tissue 3: $\varepsilon_r = 31$, $\sigma = 0.45$ mho/m) is inserted. The values are calibrated to an antenna current of 100 mA.

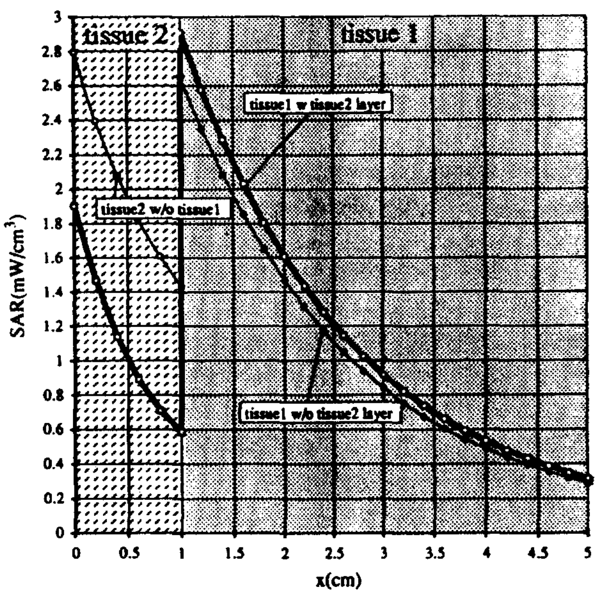

Fig. 10. SAR versus depth into a representative example of a layered plane phantom, which consists of a plane phantom simulating brain tissue (tissue 1: $\varepsilon_r = 42$, $\sigma = 0.75$ mho/m) and a 1-cm-thick layer of a simulated bone tissue (tissue 2: $\varepsilon_r = 5$, $\sigma = 0.15$ mho/m). It is exposed to a $\lambda/2$ dipole operating at 840 MHz, and the distance d between antenna axis and surface of the bone layer is 15 mm. The values calibrated to an antenna current of 100 mA are compared with those of the unlayered bone and brain phantom.

tissues and that the worst-case SAR's inside any tissues are reliably approximated by (1) and (3).

VIII. Conclusion

The absorption mechanism for the close near fields of dipole antennas for a plane phantom model is clarified and can be described by H-field induced surface currents. The spatial peak SAR can be well approximated by the suggested formula (1) or (3). These findings can be generalized to larger heterogeneous biological bodies of arbitrary shape. Accurate worst-case SAR approximations are obtained applying (1) or (3) for the human body exposed to close near fields of dipole antennas operating above 300 MHz. In most cases, SAR values averaged over 1 or 10 cm³ are well approximated assuming an attenuation equal to that of the plane wave.

A consequence of this study is that the health safety regulations for hand-held communication equipment must be revised, because the 7-W exclusion clause is not always consistent with the ANSI safety limits for the spatial local peak SAR recommended for the controlled environment (8 mW/g). For the uncontrolled environment (1.6 mW/g) the exclusion is in direct contradiction with the peak SAR limits shown by the following example. Assume that the feedpoint current of a 7-W 1.5 GHz transceiver in 2.5 cm distance from the eye tissue is increased to about 350 mA due to feedpoint changes would result in a spatial peak SAR averaged over 1 g of tissue of over 40 mW/g. Further note that in the close near field, the SAR is not directly related to the input power but to the antenna current distribution.

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References

[1] ANSI C95.1-1982, *American National Standard Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 300 kHz to 100 GHz.* New York: IEEE Press, 1982.

[2] ANSI C95.1-1990, *Final Draft: American National Standard Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 300 kHz to 100 GHz.* New York: IEEE Press, 1990.
[3] L. Slesin, "Some hand-held two-way radios may present health risk," *MicroWave News*, vol. 10, pp. 1–2, Dec. 1990.
[4] Q. Balzano, O. Garay, and F. R. Steel, "Energy deposition in biological tissue near portable radio transmitters at VHF and UHF," in *Conf. Rec., 27th Conf. IEEE Veh. Technol. Group*, Mar. 1977, pp. 25–39, .
[5] ——, "Heating of biological tissue in the induction field of VHF portable radio transmitters," *IEEE Trans. Veh. Technol.*, vol. VT-27, pp. 51–56, May 1978.
[6] ——, "Energy disposition in simulated human operators of 800-MHz portable transmitters," *IEEE Trans. Veh. Technol.*, vol. VT-27, pp. 174–188, Nov. 1978.
[7] I. Chatterjee, Y.-G. Gu, and O. P. Gandhi, "Quantification of electromagnetic absorption in humans from body-mounted communication transceivers," *IEEE Trans. Veh. Technol.*, vol. VT-34, pp. 55–62, May 1985.
[8] A. W. Guy and C.-K. Chou, "Specific absorption rates of energy in man models exposed to cellular UHF mobile-antenna fields," *IEEE Trans. Microwave Theory Tech.*, vol. MTT-34, pp. 671–680, June 1986.
[9] S. S. Stuchly, M. A. Stuchly, A. Kraszewski, and G. W. Hartsgrove, "Energy deposition in a model of man: Frequency effects," *IEEE Trans. Biomed. Eng.*, vol. BME-33, pp. 702–711, July 1986.
[10] M. A. Stuchly, A. Kraszewski, S. S. Stuchly, G. W. Hartsgrove, and R. J. Spiegel, "RF energy deposition in a heterogeneous model of man: Near-field exposures," *IEEE Trans. Biomed. Eng.*, vol. BME-34, pp. 944–950, Dec. 1987.
[11] R. F. Cleveland and W. T. Athey, "Specific absorption rate (SAR) in models of the human head exposed to hand-held UHF portable radios," *Bioelectromagn.*, vol. 10, pp. 173–186, Jan. 1989.
[12] A. Hizal and Y. K. Baykal, "Heat potential distribution in an inhomogeneous spherical model of a cranial structure exposed to microwaves due to loop or dipole antennas," *IEEE Trans. Microwave Theory Tech.*, vol. MTT-26, pp. 607–612, Aug. 1978.
[13] O. Fujiwara, H. Higashihama, and T. Azzakami, "Calculation of face-SAR due to portable transmitter," in *Proc. Int. Wroclaw Symp. Electromagn. Compatibility*, June 1990, pp. 169–172.
[14] N. Kuster and R. Ballisti, "MMP-method simulation of antennae with scattering objects in the closer nearfield," *IEEE Trans. Magn.*, vol. 25, pp. 2881–2883, July 1989.
[15] M. A. Stuchly, R. J. Spiegel, S. S. Stuchly, and A. Kraszewski, "Exposure of man in the near-field of a resonant dipole: Comparison between theory and measurement," *IEEE Trans. Microwave Theory Tech.*, vol. MTT-34, pp. 27–31, Jan. 1986.
[16] C. Hafner, *The Generalized Multipole Technique for Computational Electromagnetics.* Dedham, MA: Artech House, 1990.
[17] L. Bomholt, "MMP-3D—A computer code for electromagnetic scattering based on the GMT," Ph.D. dissertation, ETH no. 9225, Swiss Federal Institute of Technology (ETH), Zurich, Switzerland, 1990.
[18] P. Leuchtmann and L. Bomholt, "Thin wire feature for the MMP-code," in *6th Annu. Rev. Progress in Appl. Comput. Electromagn. (ACES) Conf. Proc.*, Monterey, CA, Mar. 1990.
[19] C. Hafner and N. Kuster, "Computations of electromagnetic fields by the MMP method (GMT)," *Radio Sci.*, vol. 26, pp. 291–297, Feb. 1991.
[20] A. C. Ludwig, N. Kuster, A. Glisson, and A. Thal, "5:1 dipole benchmark case," in *The ACES Collection of Canonical Problems, Set I*, H. A. Sabbagh, Ed. Monterey, CA: Applied Computational Electromagnetics Society, pp. 34–59, 1990.
[21] N. Kuster "6 types of canonical problems based on one geometrical model," in *The ACES Collection of Canonical problems, Set I*, H. A. Sabbagh, Ed. Monterey, CA: Applied Computational Electromagnetics Society, pp. 60–81, 1990.
[22] N. Kuster and L. Bomholt, "Computations of EM fields inside sensitive subsections of inhomogeneous bodies with GMT," presented at IEEE Antennas Propagat. Soc. Int. Symp., Dallas, TX, May 1990.
[23] N. Kuster, "Internal check routine of the MMP program packages for model validation," in *Electromagnetic Modeling Software Workshop*, San Jose, CA, *IEEE Antennas Propagat. Soc. Int. Symp.*, June 1989.
[24] H. N. Kritikos and H. P. Schwan, "Hot spots generated in conducting spheres by electromagnetic waves and biological implications," *IEEE Trans. Biomed. Eng.*, vol. BME-19, pp. 53–58, Jan. 1972.

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